

# ***Air, Thermal, and Water Management for PEM Fuel Cell Systems***

**Honeywell International  
Torrance, CA**

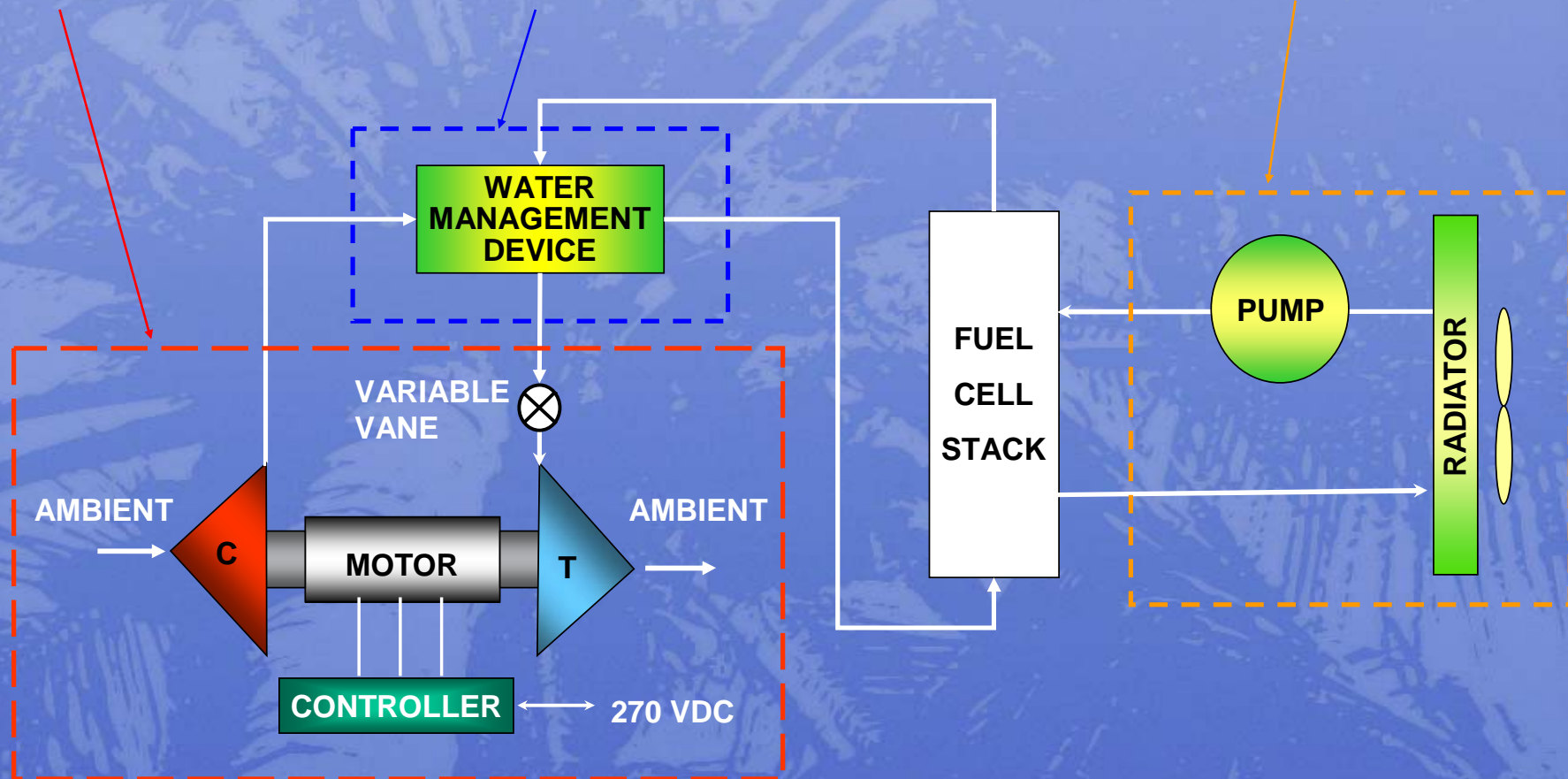
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**Honeywell**

## Air Management

## Water Management

## Thermal Management





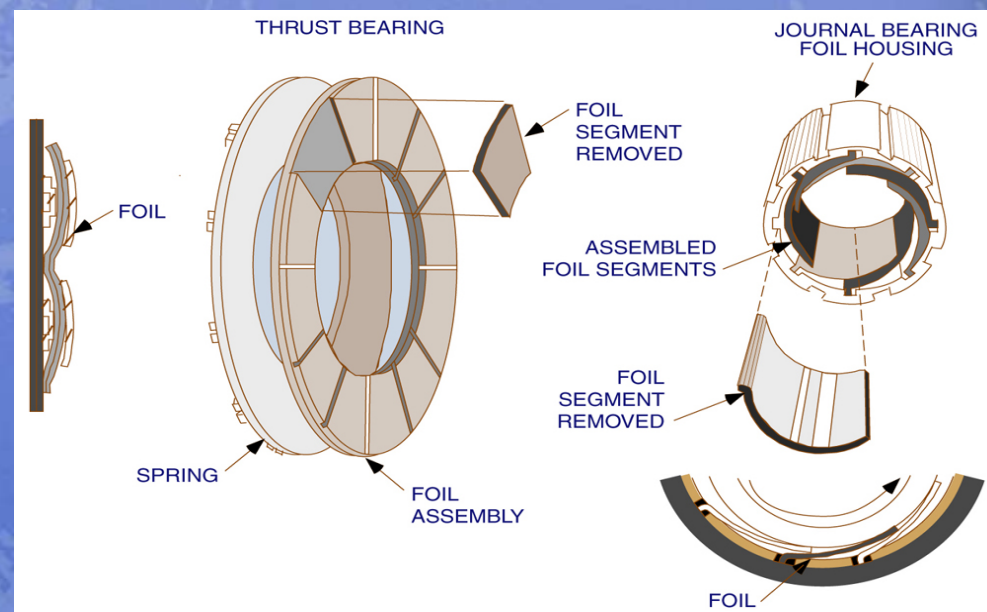
- Net fuel cell system power: 80 kW
- Mass flow: 100gr/sec @ 2.5 pressure ratio
- Cathode inlet humidity: 60% RH at 80°C
- Anode inlet humidity: Not applicable
- Turbocompressor power consumption: 6kW
- TWM system power consumption: 2.4kW
- Stack heat rejection: 60 kW
- Operating conditions
  - Steady state only
  - Ambient conditions: hot and standard (+40 and +20°C)

- Contamination free air flow to fuel cell
  - Compliant foil air bearings (no lubricants)
- Low production cost potential
- Zero Maintenance
- Reliable - one moving part
- Lightweight/Compact
- Efficient
- High temperature capable expander/turbine
- Variable geometry turbine maximizes efficiency
- Modular

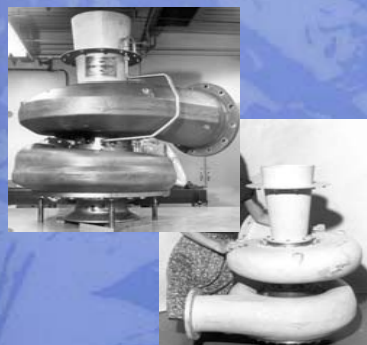




- Developed by Honeywell
- Over 30 years of proven performance
- High-speed efficiency
- Compact
- No maintenance
- Up to 80k hours of continuous operation
- 50k start/stops
- Low life-cycle costs



***Foil Air Bearing Technology Provides Long Operating Life without Oil Lubrication***



2 Bootstrap Turbocompressors  
(Full and Partial Flow Sizes)  
TEPCO 5MW  
Phosphoric Acid  
Fuel Cell Power Plant  
1981



Demonstration of Motor Driven  
Turbocompressor  
w/315degC Temperature Capability  
Turbine in  
DoE/Honeywell 50kW PEM Fuel Cell  
System  
2001



Motor Driven Turbocompressor  
PEM Fuel Cell System  
for Unmanned Aerial Vehicle  
2003



Motor Driven Turbocompressor  
DoE 50kW PEM Fuel Cell  
System  
for Light Duty Vehicle  
2003



Demonstration of  
Motor Driven Turbocompressor  
w/Mixed Flow Compressor and  
Variable Nozzle Turbine  
DoE 50kW PEM Fuel Cell System  
for Light Duty Vehicle  
2001



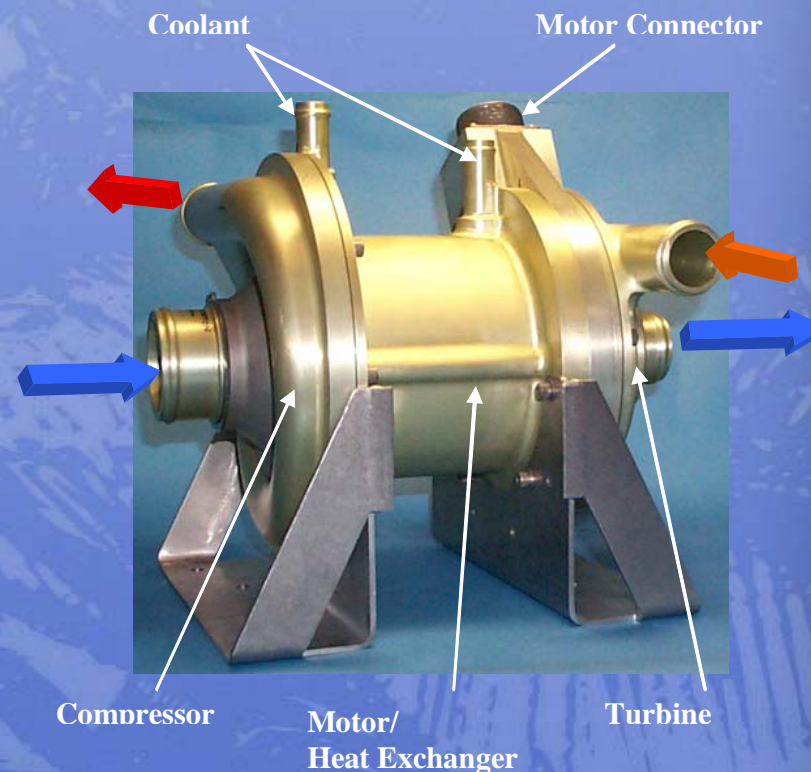
Demonstration of Motor  
Driven Turbocompressor  
DoE 50kW PEM Fuel Cell System  
for Light Duty Vehicle  
1997

**Honeywell is a Leader in Foil Air Bearing Turbomachinery for Fuel Cells**



- Enhanced design for 50-80kW systems
- Compliant foil air bearings
- Lightweight/Compact - 15 kg/15 liters
- Reliable - One moving part
- Low production cost potential

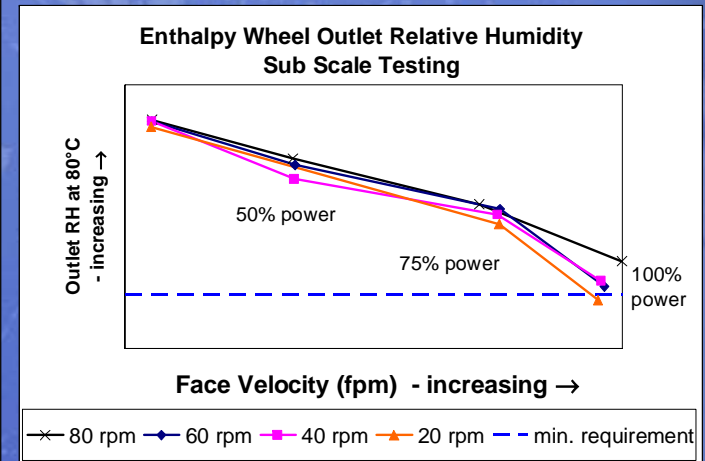
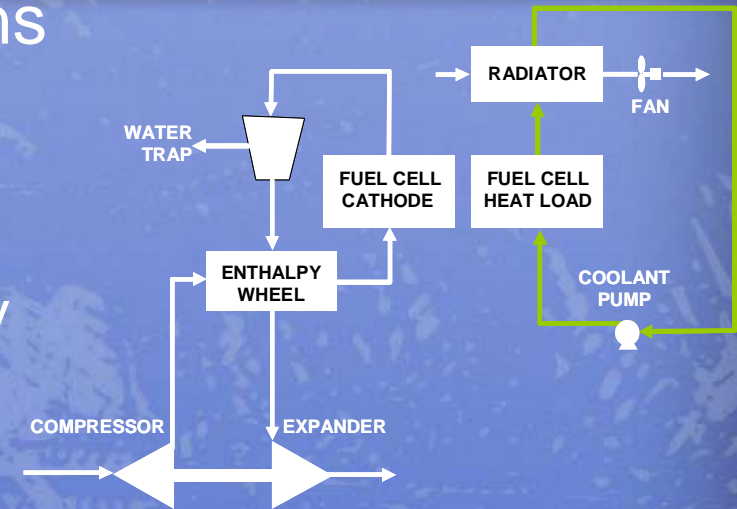
	Efficiency (%)	Pressure Ratio	Flowrate (gr/sec)	Power
Compressor	72	2.5	100	
Turbine	80	2.5	100	
With turbine		2.5	100	6kW
Without Turbine		2.5	100	16kW



# FUEL CELL Water Management – Adsorbent Wheel

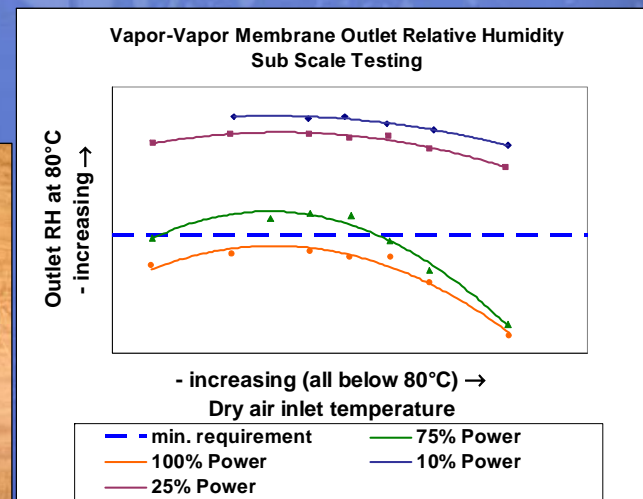
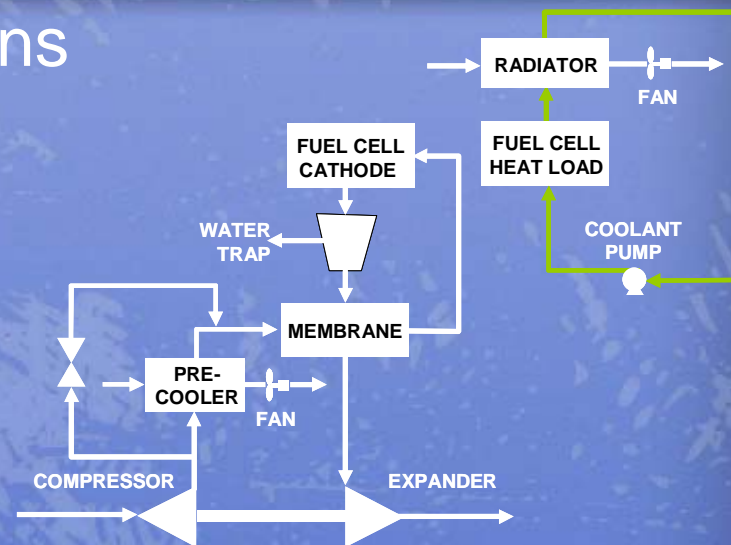
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- Detailed system design and specifications
  - Emprise adsorbent wheel used
- Sub-scale component testing
  - Performance strong function of face velocity
  - $dP < 7\text{kPa}$
  - Power:  $< 100\text{W}$
  - Leakage  $< 1\%$  process flow
- Full scale design – Emprise
  - 8" Ø, 7" length wheel
  - vol: 17l; wt: 17kg
  - Anodized Al construction
  - Seal tension controlled with tie rods





- Detailed system design and specifications
  - Nafion membrane (Perma Pure)
  - Pre-cooler dP ~ 7kPa
  - Pre-cooler fan pwr: 0.6 kW
- Sub-scale component testing
  - Performance sensitive to temperature
  - Membrane dP ~ 14kPa
- Full scale design – Perma Pure
  - 6" Ø, 10" length cartridge
  - 6.4m<sup>2</sup> Nafion
  - vol: 20l; wt: 6kg



# FUEL Thermal Management – Trade Study

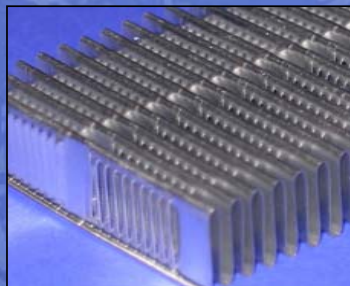
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- Analysis of stack waste heat rejection options
- Utilize system weight (wt)
- System wt = HX wt + fan wt + parasitic pwr/stack specific pwr
- System level evaluation of HX weight

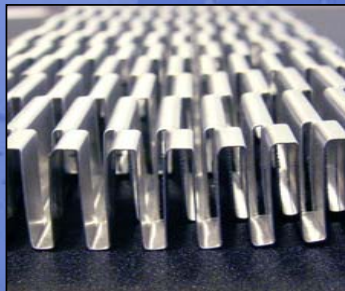
## Technologies evaluated

Radiator Trade Study Technology/Design Matrix				
HX Design	HX Technology			
	Baseline	Advanced	Microchannel	Al Foam
Aerospace Plate Fin	Offset fin	NA	Plain fin	20 ppi
Automotive Tube Fin	Louver fin	Louver fin	Plain fin	40 ppi

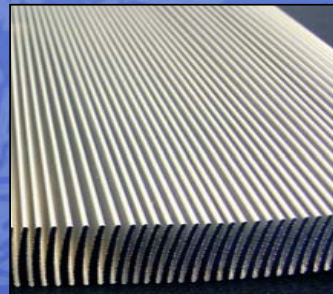
Louver fin



Offset fin



Microchannel fin



Foam





- Problem Statement
  - 60 kW max steady state heat rejection
  - 6.5% grade at 55 mph w/ 600kg payload

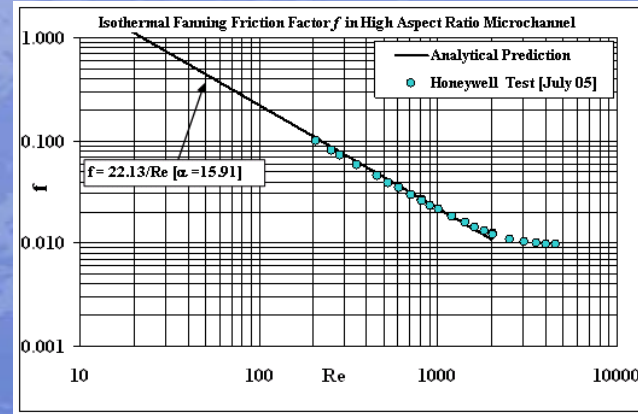
Heat rejection rate = 60 kW		
<b>Hot flow:</b>	Glycol/water (50/50)	
Flow Rate:	370 lb/min (2.8 kg/sec)	
T <sub>in</sub> :	167 °F (75 °C)	ΔT: 35 °C
P <sub>in</sub> :	50.3 psia	
<b>Cold flow:</b>	Air	
T <sub>in air</sub> :	104 °F (40 °C)	ΔT: 35 °C
P <sub>in air</sub> :	14.7 psia	

- Results

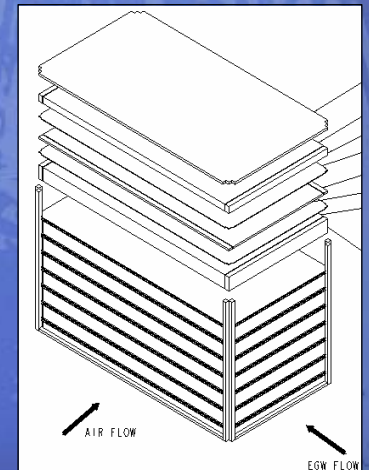
	Face Area [cm <sup>2</sup> ]	Thickness [cm]	System weight [kg]	Power [kW]
Automotive Baseline	3,600	3.2	19.4	6.0
Automotive Advanced			17.2	4.1
Automotive Microchannel			14.4	2.1
Automotive Al Foam			11.6	1.7

- *Al foam shows best performance vs. automotive baseline*
  - *For same size – 70% system power reduction*
  - *– 30% system weight reduction*

- Microchannel
  - Predictions based on laminar flow theory
  - Fabricate prototype
  - Fin only isothermal pressure drop (f test)
    - Results consistent with analytical predictions



- Aluminum foam
  - Predictions based on published data
    - Kim, et al. *JHT*, Transactions ASME, v 122, n 3, Aug, 2000, p 572-578
  - Fabricate prototype
  - Identified fouling as possible issue





- Complete turbocompressor testing – 2006
- Validate humidifier performance – 2006
- Validate heat exchanger performance – 2006
- Build & test a full scale aluminum foam radiator – 2006
- Evaluate aluminum foam manufacturing – 2006
- Demonstrate air, thermal & water management system – 2007

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- Honeywell Transportation Systems
- Emprise Corporation
- Perma Pure LLC

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